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Systematic Histological Examination of the Central Nervous System of a Case of Transverse Lesion of the Spinal Cord in the Lower Cervical Region.

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T. T., aged 14, suffered from a fracture-dislocation of the spinal column in the mid-cervical region, as the result of a motor-cab accident. The patient was admitted to Charing Cross Hospital under the care of Mr. Stanley Boyd, and was seen by Dr. F. W. Mott, to whom we are indebted for the opportunity of examining the central nervous system, and for the following brief notes of the case:—

Shortly after the accident there was found to be complete flaccid paralysis of the trunk and limbs, breathing being wholly diaphragmatic, and the only movements which remained were slight flexion and pronation of the forearms. All the deep reflexes were absent, and the plantar response was at first flexor, and later doubtful extensor in type. Later he recovered some movements in the right arm and slight voluntary flexion of the thighs, which was accompanied by spasticity of the lower limbs. There was at first marked comparative loss of all forms of sensation in the legs, with almost total loss in the trunk up to the level of the first rib, but ultimately sensation improved considerably, with the exception of the thermic sensibility, which remained very markedly impaired. For some days after the accident there was incontinence of urine and fæces, followed later by persistent retention, and priapism

[1] From the Pathological Laboratory of the London County Asylum, Claybury, Essex.

was a marked feature throughout. The patient died eight weeks after the accident.

The brain-stem and spinal cord were hardened in Müller's fluid for a period of five months, while the cerebellum, mid-brain, and cerebral hemispheres were in 5-per-cent. formalin solution for the same period. Sections from the brain-stem and spinal cord were stained by (1) Marchi's method; (2) Weigert's and Weigert-Pal's method; (3) Hæmatoxylin and Van Gieson's stain. The sections stained by Weigert's method and Pal's modifications showed practically no changes, and those described were seen in the sections stained by the Marchi method. Sections from the mid-brain, cerebellum, and cerebral cortex were stained by (1) Marchi's method; (2) Nissl's method.

It is proposed to discuss, firstly, tract degenerations ascending and descending from the lesion, which was found to be situated at the level of the fifth cervical segment; and, secondly, the changes resulting therefrom in the cells of origin of the injured fibres.

Descending Degenerations.

In the anterior columns: A well-defined tract on either side of the anterior median fissure was found to be degenerated as low down as the third sacral segment. The degeneration in this situation was almost as well marked in the region of the fourth lumbar segment as in the dorsal region, but below the lumbar region the number of degenerated fibres rapidly diminished, and none could be observed below the third sacral segment. Well-marked degenerations of a somewhat scattered nature were also present in the region of the rubrospinal and Deiters' descending tracts, a few degenerated fibres being still present at the level of the third sacral segment (*vide* figs. 1—6). Very marked degeneration was present in the crossed pyramidal tracts throughout (*vide* figs. 1—6).

Posterior columns: Well-marked degenerations of the endogenous descending tracts of the posterior columns were present. The comma tract was degenerated as low as the ninth dorsal segment, while below this region the septo-marginal tract was degenerated as far as the third sacral segment, where only a few degenerated fibres, situated quite superficially on either side of the posterior fissure, were to be observed. Flechsig's oval area was very definitely degenerated below the ninth dorsal segment, and could be seen as far down as the last lumbar, but not in the sacral segments. In the dorsal region many degenerated

Fig. 1.

Third sacral segment.

Fig. 4.

Seventh dorsal segment.

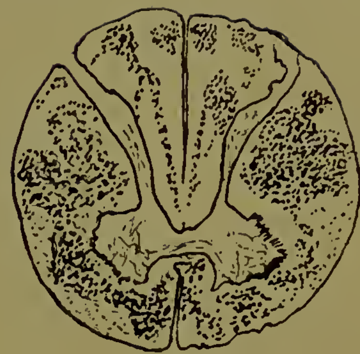

Fig. 7.

Sixth cervical segment,
level of lesion.

Fig. 2.

Fourth lumbar segment.

Fig. 5.

Third dorsal segment.

Fig. 8.

Fourth cervical segment.

Fig. 3.

Ninth dorsal segment.

Fig. 6.

Second dorsal segment.

Fig. 9.

Third cervical segment.

Sections of the spinal cord at various levels to show the degenerated fibres stained by Marchi's method. (Drawn with Edinger's projection apparatus.)

fibres were present close to the grey matter in the deeper portion of the columns. Degenerated fibres were noticed within the grey matter, especially in the region of the anterior horns, while the posterior portions of the grey matter were comparatively free (*vide* figs. 1—6).

Level of the lesion, fifth and sixth cervical segments: The degeneration was extremely diffuse throughout all regions of the cord, though less marked in the deeper portions of the columns of Goll than elsewhere. On the whole, however, the regions of the efferent tracts showed a more intense degeneration than those of the afferent tracts. The grey matter also showed considerable degeneration. Many degenerated fibres were present in the posterior roots, and could be seen proceeding thence in the direction of the anterior horns. The grey commissures showed degeneration, which was especially well marked in the anterior commissure. Great numbers of degenerated fibres could be seen sweeping out from the region of the anterior horn cells. Sections stained with hæmatoxylin and Van Gieson's stain showed an intense inflammatory reaction, slighter in the white matter, but very intense in the grey matter, where the vessels were dilated and surrounded with large collections of round cells, and in many places tiny capillary hæmorrhages could be seen (*vide* fig. 7).

Ascending Degenerations.

In the posterior columns a very intense degeneration of the fibres of the columns of Goll and Burdach was present, more especially of those of the deeper portions, while the root zones and the region of the comma tract were comparatively free. Above the sensory decussation the mesial fillet still showed a considerable number of scattered degenerated fibres (*vide* fig. 12). The combined fillet in its passage through the mid-brain showed a much greater degeneration owing to the large number of degenerated fibres which had entered it from Gowers' tract. The direct cerebellar tracts appeared entirely degenerated, and could be traced through the restiform bodies, of which they formed the superficial dorsal portion, into the cerebellum, the degenerated fibres going partly into the middle lobe, and partly into the lateral lobes. The greater number of these degenerated fibres could be traced up to the granular layer of the cortex, but none were seen among the cells themselves, while others, much fewer in number, appeared to pass directly to the neighbourhood of the cells of the dentate and roof nuclei.

Such a distribution of the fibres entering the cerebellum from the cord agrees with the results obtained in animals by Horsley and Clarke [3]. By this arrangement the effector cells of the cerebellum—i.e., those of the dentate and roof nuclei—are placed in a similar position to those of the cerebrum—i.e., the Betz cells of the ascending frontal convolutions—both receiving impulses from the afferent system as well as from the association areas of their respective cortices.

The antero-lateral ground bundles showed well-marked degeneration of Gowers' tracts, which were traced upwards through the brain-stem

FIG. 10.
Section through upper part of pons.

FIG. 12.
Section through medulla, mid-olivary region.

FIG. 11.
Section through mid-pons.

FIG. 13.
Section through medulla at level of pyramidal decussation.

Sections through the brain-stem, showing degenerated fibres stained by Marchi's method.

to the upper portion of the pons, giving off as they ascended a large supply of fibres to Deiters' nucleus. In the upper pontine region the tracts subdivided, one portion passing by means of the superior cerebellar peduncle into the cerebellum, while the remainder joined the fillet. A considerable amount of degeneration was also observed in the anterior ground bundles, and this could be traced through the brain-stem in the continuation of these bundles in the posterior longitudinal bundles. Of these degenerated fibres in the posterior longitudinal bundles many passed to the region of Deiters' nuclei, others into the valve of Vieussens, and the remainder largely into the corpora quadrigemina. Longitudinal sections showed large numbers of degenerated fibres sweeping from the mesencephalon to the lateral nucleus of the thalamus.

Well-marked degeneration in the grey matter of the cord could be observed for a distance of three segments above the lesion, the degenerated fibres sweeping across the anterior commissure. A slight amount of retrograde degeneration was seen in the pyramidal tracts above the lesion, but only a few fibres were affected.

Cell Changes.

The cells of the grey matter of the spinal cord appeared quite normal, with the exception of those of Clarke's columns. Here there were very marked changes, most of the cells being globular with absent or excentric nuclei, and marked diminution of the tigroid substance. None of the cells of these columns appeared to be normal, but the degree of degeneration showed considerable variability (figs. 14—15).

In Deiters' nuclei many of the large cells showed considerable change, being swollen and irregular in shape. Their nuclei were excentric, and more or less marked chromatolysis was present (fig. 14, 3). On the other hand, some few of the large cells and all the small cells were quite normal in appearance.

The cells of the red nuclei seemed to be distinctly diminished in number, and for the most part the large cells present were very irregular in shape and the nuclei were excentric and pale, the cell-body staining poorly by Nissl's method and exhibiting marked chromatolysis. Satellite cells could be seen in many cases in juxtaposition to the irregular cell-walls, and the position of these cells distinctly suggested that they were acting as phagocytes. The appearance presented by these cells of the red nucleus was in striking contrast to that of the normal cells of the third nerve nucleus in the same section (fig. 14, 5 and 6).

The cells of the locus niger were affected in varying degrees, many being perfectly normal while some showed definite chromatolysis and nuclear excentricity (fig. 14, 4).

Sections of the central convolutions taken from the motor area of the cerebrum, as shown in the figures, were stained by Nissl's method and by modifications of this method—e.g., polychrome blue.

Section I, from the mesial surface of the leg area (fig. 15), showed in all nineteen Betz cells, only three of which can be described as quite normal in appearance, the remainder presenting every degree of chromatolysis, from slight perinuclear involvement to total disappearance of the Nissl bodies throughout the entire cell.

Some few of the cells persisted as mere irregular ghosts, taking practically no stain and presenting no nucleus, while the majority showed considerable excentricity of the nucleus, with appearance of vacuolation and a moderate degree of chromatolysis. The cells presenting marked changes had in many cases "satellite cells" lying in irregularities of their outline. The large pyramidal cells appeared quite normal, and no changes could be observed in the post-Rolandic region.

Section II (*vide* fig. 16): Twenty-four Betz cells were counted; nine of which were practically normal in appearance. One definite ghost cell was seen, and the remaining fourteen cells showed varying degrees of chromatolysis and nuclear excentricity. Again the large pyramidal cells and the cells of the ascending parietal convolution appeared quite normal, and this was the case in all the sections examined.

Section III, from the upper arm area (*vide* fig. 16), shows eleven Betz cells, eight of which were normal, the remaining three showing definite chromatolysis and nuclear excentricity.

Section IV, from the lowest part of the arm area (*vide* fig. 16): Eight cells were counted, three of which were fairly normal, while the remaining five showed excentricity of the nucleus and a considerable amount of chromatolysis.

Section V (*vide* fig. 16): Here the Betz cells are considerably smaller than in the other sections, and of six cells counted, five were quite normal, while one showed slight perinuclear chromatolysis.

Section VI (*vide* fig. 16): The Betz cells, of which six were seen, were still smaller in size, and all appeared normal.

Section VII, face area: Four cells were seen, all of which were normal.

Fig. 14.

Cells from spinal cord and brain-stem. (1) Anterior horn cell, normal, and (2) cell of Clarke's column, showing marked chromatolysis and excentricity of nucleus. These cells are from the same section of the fifth dorsal segment, and show the contrast between the degenerated cells of Clarke's column below the lesion and the normal cells of the anterior horn cell similarly stained. (3) Cell of Deiters' nucleus, showing chromatolysis and nuclear excentricity. (4) Cell of locus niger exhibiting similar changes. (5 and 6) Cells of red nucleus, showing varying degrees of chromatolysis and excentricity of nucleus. (7) Normal cell of third nerve nucleus from same section as (5 and 6), to show contrast between the cells of this nucleus and those of the red nucleus.

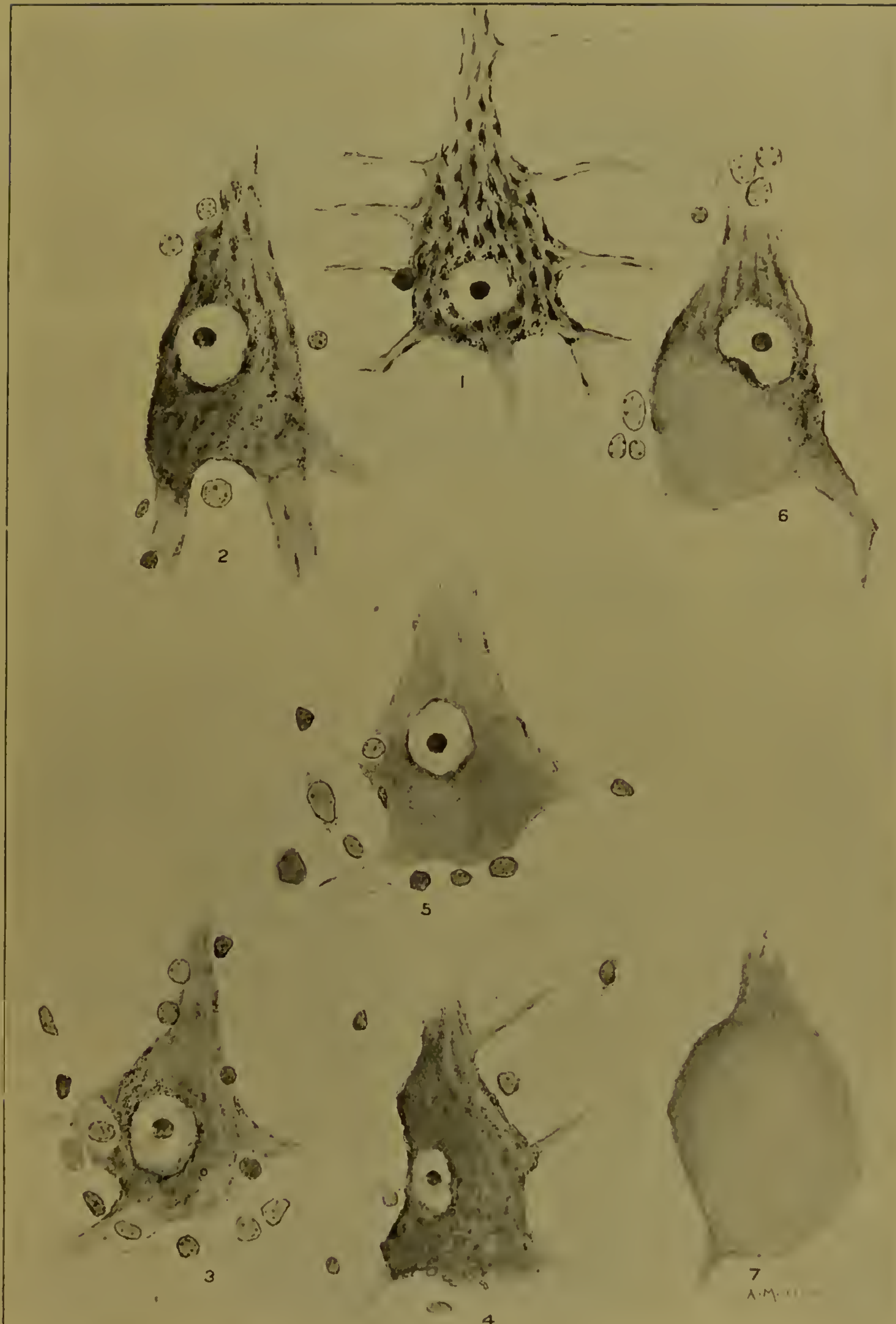

Fig. 15.

Betz cells from motor area of cortex, showing all stages of chromatolysis and nuclear excentricity from (1) the normal cell to (7) a cell with completely extruded nucleus, the cell being swollen and showing no trace of tigroid substance. Satellite cells are seen around many of the Betz cells.

The above description gives an account of an average section of each of these areas, and summarizes the results obtained from the examination of a large number of sections in each case. The changes in the cortical cells of the two hemispheres were similar.

Comments.

Two points seem worthy of special mention in connexion with the degenerations described :—

(1) The definite tract degeneration which was present on either side of the anterior median fissure as far down as the third sacral segment. This tract was well marked down to the level of the fourth lumbar segment, but the degenerated fibres rapidly lessened in numbers in the sacral cord, had almost entirely disappeared by the time the third sacral segment was reached, and could not be recognized below this. The direct pyramidal tract is usually described as ending at the lower dorsal or first lumbar segment, and we regard the degenerated fibres seen in our case as representing the tract originally described by Mott [4] as descending the cord from Deiters' nuclei or cranial motor nuclei.

(2) It is of very great interest to notice the large direct afferent supply from the limbs received by Deiters' nucleus by means of its connexions with Gowers' tract and the fibres ascending from the cord in the posterior longitudinal bundles (*vide* fig. 17).

In this respect our results differ considerably from those of Fraser [1], who, in an experimental inquiry into the results of lesions in the posterior longitudinal bundle of animals, was able to obtain only slight ascending degeneration from the cord to Deiters' nucleus, and concluded that the supply of afferent fibres from the cord to Deiters' nucleus in these bundles was insignificant. Such large afferent connexions as we found, when considered together with the fibres coming to Deiters' nucleus from the vestibular nerves and from other important cranial nerves by means of the posterior longitudinal bundle, place that nucleus in an excellent position to act as a great co-ordinating and equilibrating centre, as has been so often suggested.

The reasons why the cells of the central cortex show such varying amounts of change are rather difficult of explanation. It has been suggested by Dr. Mott that the real reason of this variability lies in the fact that the changes present in a cell after such a lesion are proportional to the amount of injury done to the total neurone. If a

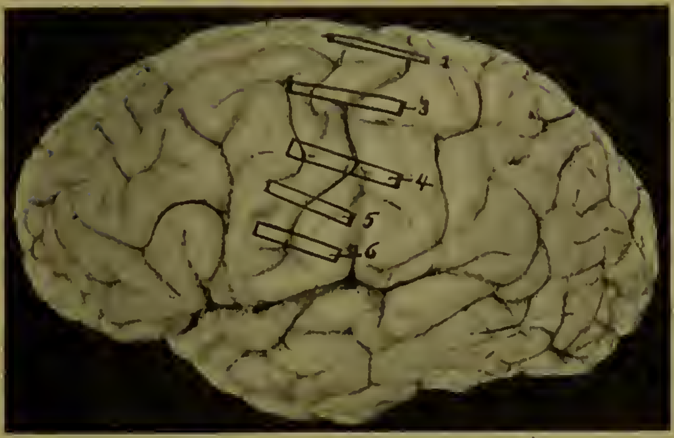

FIG. 16.

Showing the parts of the cortex from which the sections were made. Section 1, on the mesial surface of the leg area, is not shown, nor is section 7 from the face area. Similar sections were taken from the opposite hemisphere.

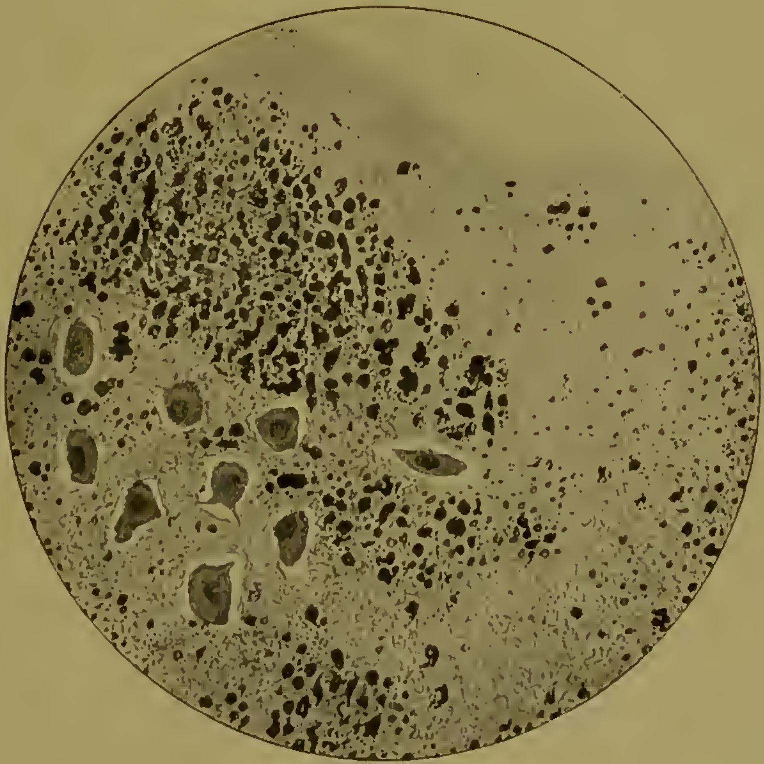

FIG. 17.

Showing degenerated fibres round cells of Deiters' nucleus (semi-diagrammatic).

neuraxon has already given off a large number of collaterals above the place of injury, then the changes in the cell will be only transitory and the cell will in all probability completely recover. This would explain the fact that the cells of Clarke's column presented fairly uniform changes, while the cells of the cortex and of Deiters' nuclei presented a varying amount of change, as the degeneration would depend inversely on the number of collaterals given off from the axons of the cells above the seat of injury. On the other hand, there was a very slight amount of movement in the thigh and some movement in the arms after the accident, so that it is probable that at least some of the fibres of the pyramidal tracts escaped injury.

Our observations are in entire agreement with the results obtained by Gordon Holmes and Page May [2], in that the only cells of the cortex we found affected were the large Betz cells of the ascending frontal convolutions, and the large pyramidal cells were everywhere perfectly normal.

In conclusion, we wish to thank Dr. Mott for his kindness in giving us the material and for his help in the work.

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